1. INTRODUCTION

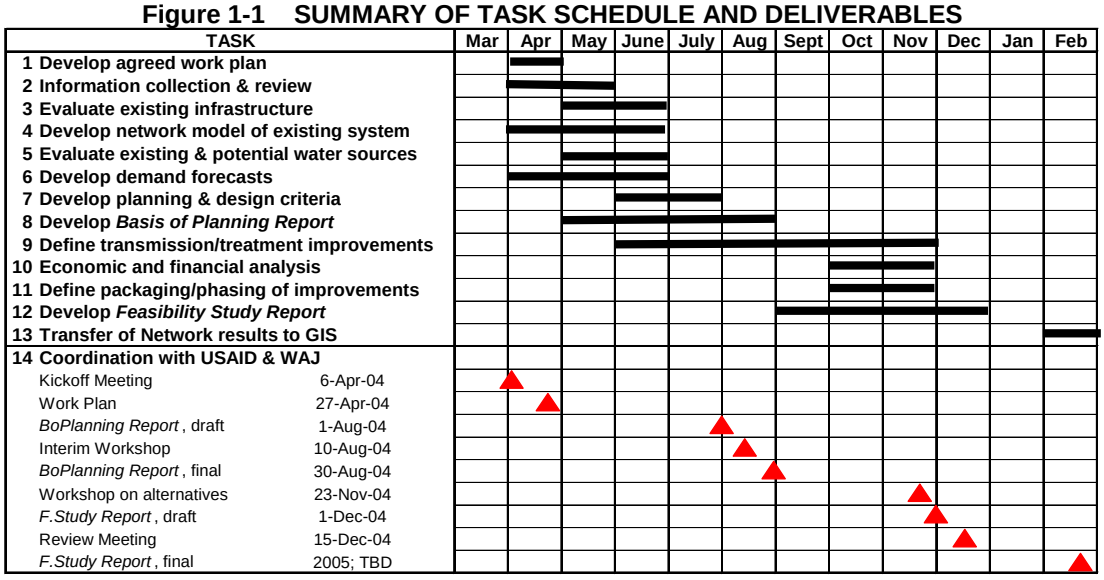
1.1 Objectives of the Feasibility Study

The desired output from the Feasibility Study is a prioritized list of projects that are required through year 2030, consisting of municipal water supply facilities needed within the service area of the Northern Governorates Water Authority (NGWA). These facilities will comprise water transmission mains and associated components: distribution storage reservoirs, pump stations, water treatment plants, groundwater wells, water-resources facilities and a centralized monitoring and control system. These facilities are to be identified under the Feasibility Study, taking into account: the balance between available water resources and water demands (residential, commercial, industrial, irrigation); expanded water facilities or demand-management measures to address forecasts of water demands and localized imbalances in available resources; the possible need for rationing of limited supplies; and, minimizing the cost of the system improvements, taking into account both the capital costs and the annual operation and maintenance (O&M) costs.

1.2 Background and Work Plan

The notice of award for Task Order 813 was received on 17 March 2004, and the task order was signed by CDM on the same day. The CDM Chief of Party began work in Jordan on 30 March 2004, and a Kick-off Meeting was held on 6 April 2004 attended by representatives of USAID, WAJ (Water Authority of Jordan) and NGWA (Northern Governorates Water Authority). In accordance with the requirements of Task Order 813, a draft Work Plan was submitted within 3 weeks after the Kick-Off Meeting. The draft was discussed and reviewed by WAJ, NGWA, and USAID, and a final Work Plan was completed on 3 May 2004. In general, the tasks and methodology described in this Work Plan are essentially the same as presented in the CDM proposal of 28 January 2004, with the schedule modified somewhat. In order to maximize coordination with the WLRP and NWMP projects, this feasibility study has been extended until 28 February 2005 to allow additional time required to incorporate the final data on the distribution reservoirs in the modeling of the proposed transmission system. The intent is that all three studies are coordinated and based on the same data and assumptions as much as possible. The schedules of the major tasks and deliverables of the Feasibility Study are summarized in **Figure 1-1**.

Figure 1-1 SUMMARY OF TASK SCHEDULE AND DELIVERABLES



The organization chart for the project is shown on **Figure 1-2**, and the staff schedule on **Figure 1-3**. These are in accordance with the final Work Plan completed on 3 May.

FIGURE 1-2 ORGANIZATION CHART

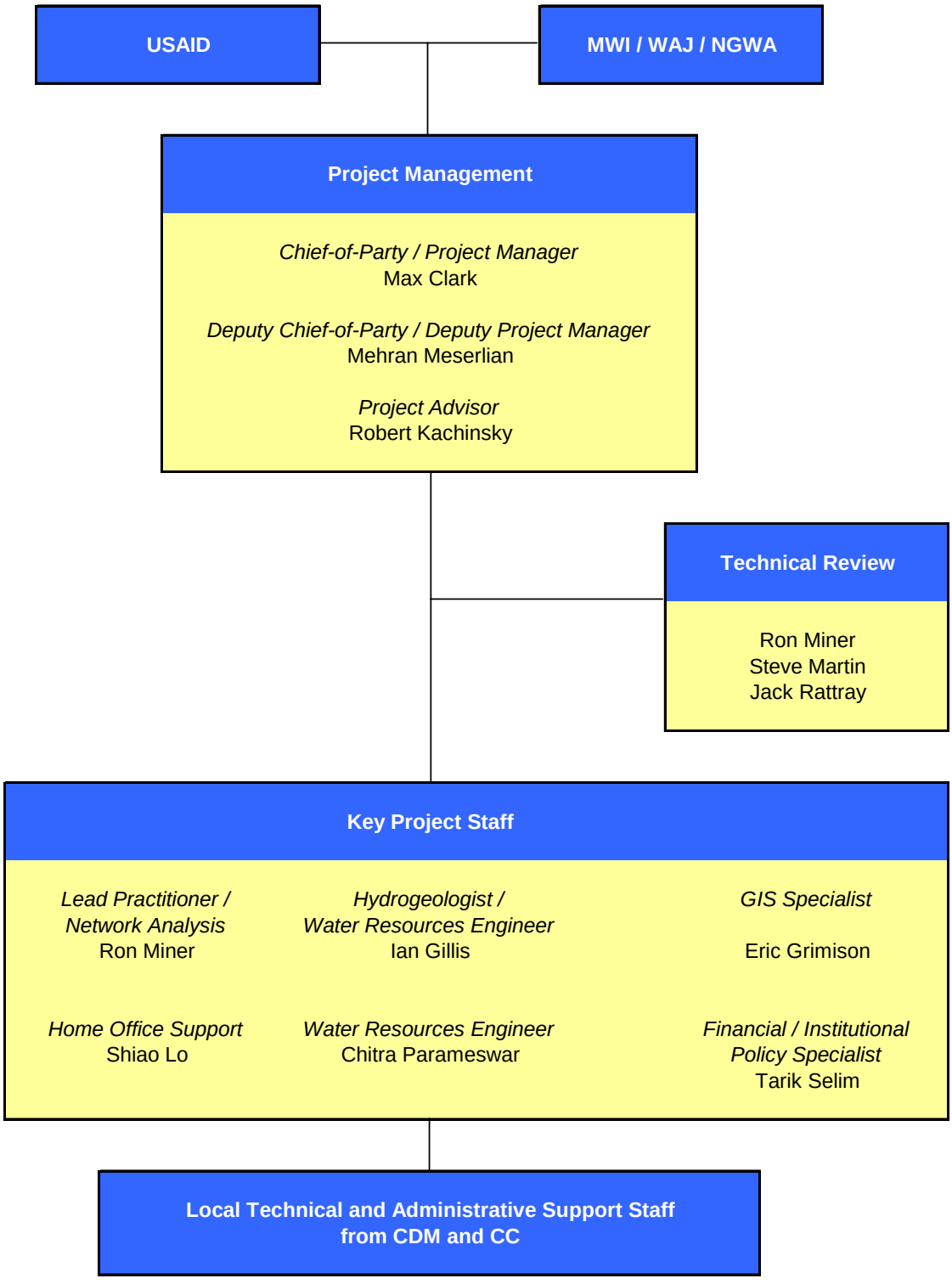


Figure 1-3 STAFFING SCHEDULE

Name	Position	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb
CDM Overseas Staff													
Max Clark	Chief of Party												
Mehran Meserlian	Deputy CoP												
Bob Kachinsky	Project Advisor												
Ian Gillis	Hydrogeologist												
Chitra Parameswar	Water Res. Engineer												
Ron Miner	Network Analyst												
Tarek Selim	Financial Analyst												
Jack Rattray	Technical Review												
Steve Martin	Treatment Specialist												
Scott Lindell	Instr & Control Spec.												
Sherry Lo	HO Support												
Laura Harvey	Tech. Editor												
CDM Local Staff													
Ahmed Abu Hijleh	Hydrogeologist												
Ayman Halaseh	Jr. Civil Engineer												
Sania Labadi	Admin. Manager												
Hala Mawajdeh	Financial Manager												
Lana Massannat	Admin. Assistant												
Hamza Habila	Office Helper												
Maher Mezher	Driver												
CC (local consultant)													
Dr. Sawsan Himmo	Hydraulic Engineer												
Dr. Adnan Al-Saliha	Hydraulic Engineer												
Aladdin Arafeh	Mechanical Engineer												
Mahmoud Fararjeh	Electrical Engineer												
Tamim Abodaqa	GIS/Hydraulic Modeler												
Saeda Qadooura	GIS/Hydraulic Modeler												
Majd Tuqan	Junior Engineer												
Hasan Nasseef	Junior Engineer												
Amman Survey Office (surveying)													
Arab Center (geotechnical)													
IB Law (review of water laws)													

Full-time assignment
Intermittent assignment; participation as needed

1.3 Background on the Study Area

The study area covers 4 of the 12 governorates of Jordan – Irbid, Ajlun, Jerash and Mafraq – which are served by the Northern Governorates Water Authority (NGWA), an operations unit of the Water Authority of Jordan (WAJ). The study area is bordered to the north by Syria and the Yarmouk River, to the west by the Jordan River, to the south by the Amman-Zarqa metropolitan area, and to the east by Iraq. The northern governorates contained about 1.56 million people in 2003, or about 29% of the national population on 32% of the national land area. The major city is Irbid with a population of 400,000, placing it as the third largest city in Jordan after Amman and Zarqa. In contrast to Irbid, the Mafraq governorate covers a large sparsely-populated desert area, in which the eastern portion contains only isolated settlements that receive water supply from local NGWA wells; this eastern portion of Mafraq has not been considered in any detail in this feasibility study on water transmission systems.

A brief statistical summary for the study area is given in **Table 1-1**, including the population, land area, and the NGWA water supply statistics for the year 2003.

The major population centers served by NGWA are located on a high plateau of rolling hills at elevations ranging generally from 400m to 900m above sea level. However, the study area also includes deep wadis and agricultural land along the Jordan River, lying at elevations as

low as 200m below sea level; and smaller settlements ranging up to 1200m above sea level. While much of Jordan is arid or semi-arid, the urbanized portion of the study area receives the highest annual rainfalls in the country, exceeding 600mm in some areas. As part of the Fertile Crescent and the ancient Cradle of Civilization, the water resources of the study area have been developed since ancient times. The rainfall statistics in **Table 1-2** for stations within the study area illustrate the strong seasonal pattern of rainfall, with 80% of annual rainfall occurring in the 4 winter months of December through March. The lack of rainfall in the summer months spurred the natural selection of wild wheat and other grains, which have developed (over millions of years, perhaps) tough seeds that can survive the hot summer and sprout in the winter rains. Irrigation from springs was developed in ancient times. Historically, water needs were supplied from karst springs and shallow wells, but many of these have been dried up by the abstractions from deep wells in recent years. In Jerash and Ajloun, where the karst geology is not favorable for deep wells, the long hot summers and reduction in spring flows have reduced the nature of agriculture in more recent times to olive trees and other rain-fed crops. Although Mafraq receives little rainfall, many deep wells have been installed to capture groundwater flows, much of it originating in the Syrian highlands. Much of the area is covered by rock and impervious layers, which limit the groundwater infiltration to less than 5% of the annual rainfall. Small-scale rainfall harvesting has been practiced since ancient times. The topography and groundwater aquifers do not lend themselves to reservoir storage of infrequent heavy precipitation and injection wells or recharge basins.

The service area is a net exporter of water to the remainder of Jordan, as well as to Israel. The Yarmouk River on the northern boundary of the service area has by far the largest streamflow of any river or wadi in Jordan, with a highly-variable flow averaging about 420 MCM at its mouth. Hydrologic models have been developed to estimate the Yarmouk stream-flow record from rainfall records covering the upstream areas in Syria, where the size and number of reservoirs and other flow regulating structures are relatively insignificant. Aside from the Yarmouk River itself, a significant amount of groundwater enters the study area from the Syrian highlands, estimated at 68 MCM. The water exported from the northern governorates is the mainstay for irrigation in the Jordan Valley, as well as the municipal water supply for Amman and Zarqa, through the King Abdullah Canal (KAC). The KAC follows the eastern bank of the Jordan River, to supply both irrigation demands and the Zai water treatment plant within the Amman water supply system. In addition, the governorate of Mafraq contains several well fields – Aqeb, Za'tary, and Sumaya well fields – which export water to the Amman-Zarqa water supply systems. As a result, the major difficulty in meeting the future NGWA water demands is that any increase in municipal water use must be made at the expense of other areas within Jordan, or at the expense of irrigation water users in the Jordan Valley or within the study area. As indicated subsequently in Section 5, the groundwater abstractions within the study area presently exceed the safe yield of the available groundwater aquifers.

As shown in **Table 1-1**, in 2003 the four northern governorates contained about 184,000 NGWA subscribers, who had a metered or accounted-for domestic consumption of about 30 MCM (excluding known or estimated water usage for irrigation, filter backwashing in a water treatment plant, and flushing of water mains). This corresponds to a metered per capita consumption of only 55 lpcd (liters per capita per day). Water is rationed, with most customers receiving water only one or two days each week. Calculation of the net water production delivered to the 4 governorates is accomplished through a network of bulk water meters to account for the import and export of water to/from the NGWA transmission mains, and to/from the areas outside the NGWA service area (principally to Zarqa and

Amman). The net production of about 58 MCM corresponds to 107 lpcd (less than 90 lpcd in Irbid, Jerash and Ajloun) which is also quite low by world standards (typically 200 to 500 lpcd in many other developing countries, when commercial, institutional and industrial use are included). The unaccounted-for water (UFW) of 44% is high given the scarcity of water in Jordan, but about half of the NGWA water losses are concentrated in Mafraq governorate (62% UFW), where the losses are attributable to the relative aridity, lawlessness, and social problems encountered in the eastern portion of Mafraq. In Jerash, Ajloun and Irbid the UFW is much lower, at 28%, 35% and 36% respectively. In Jordan as a whole, the UFW is about 50%, composed of physical losses (leakage) estimated at 30% and administrative losses (meter under-registration, stopped meters, un-metered use, billing errors, theft) estimated at 20%. Several programs are underway countrywide (including the NGWA system) to reduce the physical losses by rehabilitation and restructuring of the distribution networks. Improvements in operations management are also being considered to reduce the administrative water losses.

The distribution of the NGWA customers is shown on **Figure 1-4**, in combination with the topography and annual rainfall of the western NGWA service area, where most of the water supply from the transmission system is consumed. Most of the customers are located in the upland areas, centered on the city of Irbid. Many of the small outlying towns are served by independent local systems, rather than by the transmission system.

Table 1-1 Statistical Summary of Northern Governorates Water Supply, 2003

Item	Notes, Data Source	Governorate					Jordan	Comparison
		Irbid	Jerash	Ajlun	Mafraq	Total	[5]	NG / Jordan
Estimated Population (2003)	Dept of Statistics	1,024,019	161,115	121,660	252,625	**1,559,419**	5,480,000	28%
Area, km^2	NGWA GIS	1,576	413	423	26,330	**28,741**	88,778	32%
Density, persons/km^2		650	390	288	10	**54**	62	88%
Estimated Families (2003)	Dept of Statistics	171,515	28,266	21,344	44,320	**265,445**	961,404	28%
Persons per Familly		6.0	5.7	5.7	5.7	**5.9**	5.7	103%
Northern Governorates Water Authority (NGWA)								
Service Area, km^2	NGWA GIS	1,581	402	403	26,300	**28,686**		
Number of Subscribers (2003)	NGWA GIS	121,747	18,964	13,614	29,664	**183,989**		
Population Served, %	Assumed	95%	95%	95%	95%	**95%**	95%	
Persons per Subscriber		8.0	8.1	8.5	8.1	**8.1**		
Authorized Consumption, MCM (2003)	[1], NGWA GIS	19.69	2.95	2.12	7.69	**32.46**		
Daily Consumption/Subscriber, m^3		0.44	0.43	0.43	0.71	**0.48**		
Daily Per-Capita Consumption, liters		55	53	50	88	**60**		
Domestic Consumption, MCM (2003)	[2], NGWA GIS	19.23	2.89	2.09	5.43	**29.64**		
Domestic Per-Capita Consumption, liters		54	52	49	62	**55**		
Net Water Production, MCM (2003)	[3], NGWA GIS	30.61	4.10	3.26	20.10	**58.08**	239.03	24.3%
Daily Per-Capita Production, liters		86	73	77	230	**107**	126	85.4%
Unaccounted-for Water, %	[4]	36%	28%	35%	62%	**44%**		
Regional Operation Units (ROUs)	NGWA	Irbid Al Koura Bani Kinana Bani Ubaid North Shouna Ramtha	Jerash	Ajlun	Mafraq North Badia	**10 ROUs**		

Notes:
[1] Consumption includes: billed use; adjusted billings; known/estimated amounts for unmetered use, irrigation, tankers, backwash/flushing water
[2] Domestic consumption excludes irrigation, backwash/flushing water
[3] Net production includes internal production, and imports/exports from/to Governorates and outside NGWA area
[4] Unaccounted-for water based on net water production and authorized consumption; excludes water losses in transmission system
[5] Water supply data for Jordan as a whole from MWI Statistical Yearbook, data for 2001

Table 1-2 Summary of Rainfall Records in the Northern Governorates

Governorate	Station	ID	Years	Month of Water Year												Annual
				Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Avg.
Mafraq	Rihab	AD0017	1945-99	3.9	24.6	47.0	49.7	52.7	40.2	12.1	1.5	0.0	0.0	0.0	0.0	231.6
Mafraq	Ibbin	AD0018	1937-98	13.0	56.9	112.1	135.3	108.0	100.0	30.1	3.6	0.0	0.0	0.0	0.0	558.9
Mafraq	Mafraq Airport	AD0019	1963-99	6.5	20.1	30.2	38.6	31.5	27.4	7.9	2.0	0.0	0.0	0.0	0.0	164.1
Mafraq	Bal'ama	AL0003	1964-99	5.0	19.2	38.8	45.9	42.6	43.1	10.9	1.7	0.0	0.0	0.0	0.0	207.1
Mafraq	Khaldiya	AL0048	1967-99	6.0	16.1	23.2	35.8	25.8	25.7	6.0	1.5	0.0	0.0	0.0	0.0	139.2
Mafraq	Um El-Jumal	AL0059	1967-99	4.0	17.4	20.3	28.4	23.3	20.8	6.3	1.5	0.0	0.0	0.0	0.0	121.9
Mafraq	Um El-Quttein	F0001	1947-00	5.3	14.1	28.7	34.2	32.4	29.3	8.6	3.2	0.0	0.0	0.0	0.0	156.0
Irbid	Al-Tayiba	AB001	1937-99	13.9	53.0	96.5	116.8	93.6	83.6	25.9	5.0	0.0	0.0	0.0	0.0	490.0
Irbid	Kh. El-Wahadneh	AB004	1950-99	13.8	48.4	85.4	87.5	76.2	64.6	19.1	3.5	0.0	0.0	0.0	0.0	398.6
Irbid	Kufrawan	AB0008	1937-99	14.1	50.1	98.8	113.4	98.2	81.2	24.9	4.1	0.0	0.0	0.0	0.0	484.8
Irbid	Kartha	AD0002	1951-99	9.6	41.9	83.2	95.8	84.5	73.1	24.7	3.8	0.0	0.0	0.0	0.0	416.7
Irbid	Kufr Saum	AD0003	1937-99	9.4	54.3	92.2	121.1	102.1	85.9	28.1	4.9	0.0	0.0	0.0	0.0	409.0
Irbid	Um Qeis	AD0005	1937-99	10.9	52.4	92.6	114.6	89.5	69.1	24.5	5.4	0.0	0.0	0.0	0.0	459.1
Irbid	Kawwara	AD0009	1937-99	8.8	39.5	62.7	78.1	71.4	63.9	18.6	3.2	0.0	0.0	0.0	0.0	346.4
Irbid	En Nueiyime	AD0011	1955-99	7.5	31.0	56.7	66.6	61.3	53.2	16.2	2.5	0.0	0.0	0.0	0.0	295.0
Irbid	Ramtha Boy Sch.	AD0012	1937-99	6.2	31.2	50.1	65.0	53.2	48.0	15.8	2.5	0.0	0.0	0.0	0.0	272.0
Irbid	Khanasira	AD0013	1950-00	4.5	22.0	38.3	47.0	42.5	34.7	9.0	1.2	0.0	0.0	0.0	0.0	199.2
Irbid	Irbid Agr. Station	AE0002	1954-99	12.0	48.4	86.5	102.3	89.6	84.6	23.8	4.5	0.0	0.0	0.0	0.0	451.7
Irbid	Wadi El-Yabis	AH0002	1962-99	14.2	37.8	57.3	71.4	54.8	47.9	12.2	3.5	0.0	0.0	0.0	0.0	299.6
Ajloun	Kufrinja	AJ0002	1937-99	15.1	68.6	121.4	152.0	123.7	102.8	28.4	4.2	0.0	0.0	0.0	0.0	616.1
Ajloun	Wadi Kufrinja	AJ0003	1951-76	6.5	27.9	55.0	61.5	54.8	46.6	14.7	2.9	0.0	0.0	0.0	0.0	269.9
Jarash	Rihaba	AF0002	1962-99	15.3	51.4	106.7	129.0	114.0	107.5	32.9	4.4	0.0	0.0	0.0	0.0	561.2
Jarash	Jarash	AL0004	1942-99	6.7	35.6	68.0	80.0	76.1	63.8	17.0	3.6	0.0	0.0	0.0	0.0	350.8
Jarash	Burma	AL0026	1962-99	6.8	41.5	82.4	116.5	82.1	83.1	23.6	3.5	0.0	0.0	0.0	0.0	439.4
Jarash	Prince Feisal Nursery	AL0036	1963-99	8.8	36.7	71.0	83.6	71.2	72.1	15.5	1.6	0.0	0.0	0.0	0.0	361.0
Jarash	Qafqafa	AL0050	1967-99	6.7	32.1	58.5	68.4	60.2	53.2	13.1	1.3	0.0	0.0	0.0	0.0	293.3
Jarash	King Talal Dam	AL0053	1969-00	14.5	74.8	129.1	181.9	158.7	130.1	29.2	4.5	0.0	0.0	0.0	0.0	722.8
Average monthly rainfall, all rainfall stations				9.2	38.8	70.1	85.9	73.1	64.3	18.5	3.2	0.0	0.0	0.0	0.0	363.1
Percentage of annual rainfall				2.5%	10.7%	19.3%	23.7%	20.1%	17.7%	5.1%	0.9%	0.0%	0.0%	0.0%	0.0%	100.0%
Cumulative percentage				2.5%	13.2%	32.5%	56.2%	76.3%	94.0%	99.1%	100%	100%	100%	100%	100%	

Source: Study on Water Resources Management in Jordan, Final Report, Vol. III, Yachiyo Engineering Co. Ltd., 2001

210,000 240,000 270,000 300,000

230,000 200,000 170,000

Irbid

Ajloun

Jarash

Mafraq

300 400 200 600 500

Legend

- Customer Distribution
- Rainfall, mm
- Northern Governorates

Elevation Legend

- 900 - 1200
- 600 - 900
- 300 - 600
- 0 - 300
- -300 - 0

DRAWING SCALE: 1:300,000	THE HASHEMITE KINGDOM OF JORDAN MINISTRY OF WATER AND IRRIGATION WATER AUTHORITY	CDM International Inc.	NORTHERN GOVERNORATES WATER TRANSMISSION SYSTEM FEASIBILITY STUDY Topography, Rainfall & Customer Distribution	PROJECT No. : 3029-42324 DRAWING No. : 1-4

1.4 Purpose and Contents of This Report

This final *Feasibility Report* is intended to summarize the results obtained over the course of the feasibility study. The final results will form the subject of discussion in a Final Workshop to be held in mid-February 2005. The final Feasibility Report has been prepared, incorporating the suggestions and refinements resulting from comments received on the draft report, and subsequently from other reviewers. The relevant topics are described in the remaining sections of this report:

- Section 2 describes the previous studies and current programs that affect this feasibility study;
- Section 3 describes the existing NGWA water supply system;
- Section 4 describes the population and water demand forecasts;
- Section 5 describes the existing and potential sources of water supply;
- Section 6 describes the planning and design criteria;
- Section 7 describes the analysis of alternative transmission systems;
- Section 8 describes the proposed projects, which include the proposed pump stations, treatment plants, local distribution-storage reservoirs and transmission pipelines to be developed in phases as new sources of water are developed, and other programs to improve the system (rehabilitation of wells, pump stations and pipelines; and installation of a centralized monitoring and control system). An economic and financial analysis of the proposed projects is included.

1.5 Acknowledgements

This report has been prepared with the advice, assistance and cooperation of many people within WAJ, NGWA, MWI, and USAID. We wish to express our gratitude in particular to Khaled Al-Kodah, Nabeel Al Zoubi, Jehad Abu-Jamous and Mohamed Ababneh of WAJ; to Khaldon Khashman, Safwan Shalabi, Ahmad Sheikah, Ahmad Albataineh, Anas Al Haliq and Fares Shuweihat of NGWA; to Suzan Taha, Nisreen Haddadin and Lana Naber of the NWMP Directorate of MWI; and to Shankar Gupta and James Franckiewicz of USAID/Amman. We also wish to thank the consultants of MWH for their cooperation in coordinating and exchanging information during the work on our separate projects. We also thank other Jordanian government agencies, including in particular the staff of the NGWA ROUs, the Department of Statistics, and the Electricity Sector Regulatory Commission.